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Use of Postmortem Computed Tomography to Detect Bowel Obstruction and its Relationship to the Cause of Death

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Abstract: Bowel distension frequently indicates bowel obstruction, which is a common diagnosis in clinical radiology. Typically, symptoms and complaints lead to radiological examinations and the detection of the etiology. Untreated intestinal obstructions can lead to a fatal outcome through cardiac failure due to septic shock. Certain of these cases undergo medicolegal investigations depending on the case history, the condition of the decedent, the location of the finding, or recent visits to medical professionals. Computed tomography (CT) is a recommended method in clinical radiology for the detection of bowel obstruction, which is indicated by bowel distension and further radiological signs (eg, the whirl sign, which indicates a volvulus). Postmortem CT (PMCT) has increased worldwide, but PMCT differs from clinical CT; thus, the question of whether PMCT is also reliable for the detection of bowel obstruction in decedents or is negatively affected by postmortem modifications should be discussed. This study consists of 10 cases displaying radiological signs of bowel obstruction. Apart from bowel distension, the most common radiological signs (whirl sign, coffee bean sign, bird beak sign, and u-shape sign) are described and depicted. All decedents underwent autopsy and had a postmortem interval of less than 72 hours. Based on these cases, we assess the reliability of PMCT for detecting bowel obstruction and determining its relationship to the cause of death.

Key Words: bowel distension, bowel obstruction, volvulus, septic shock, postmortem, computed tomography, postmortem computed tomography, Virtopsy, virtual autopsy

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Approximately 20% of acute abdominal pain cases that require surgery are caused by bowel obstruction.[1] An indicator for bowel obstruction is excessive fluid-filled and/or gas-filled distension of the bowels.[2] Typically, the diameter of the small bowel is 2.5 cm or less and of the larger bowel is 8 cm or less.[3] Computed tomography (CT) is the recommended modality for the detection of bowel obstruction because several radiological signs clearly indicate bowel obstruction on CT images.[3,4] Examples of radiological signs for bowel obstruction include the whirl sign, the bird beak sign, or the coffee bean sign for the detection of a volvulus.[5] Clinical CT has high accuracy for the detection of high-grade bowel obstruction.[6–8] Although surgery has evolved considerably, mortality due to large bowel obstruction remains high.[9] A perforation may occur at dilated bowel segments and rapidly lead to severe sepsis.[10] Depending on the case history and where the death occurred, decedents with bowel obstruction may become medicolegal cases.

Computed tomography has also become an established tool for postmortem imaging.[11–13] However, postmortem CT (PMCT) differs from clinical CT because of postmortem modifications, which are described as *normal* PMCT findings in the literature.[14] Gas accumulations and gaseous distension are frequent findings on PMCT.[14,15] Therefore, if bowel distension is present, less attention may be paid to further radiological signs of bowel obstruction. A specific sign of sepsis in living patients is hepatic portal venous gas.[16] However, intrahepatic gas (IHG) is also a common finding in postmortem imaging because of decomposition,[17] and Takahashi et al[18] demonstrated a strong correlation between the presence of IHG and intestinal distension in decedents. Thus, questions remain concerning the reliability of bowel distension and common radiological signs for the detection of bowel obstruction on PMCT and whether the detection of bowel obstruction in decedents is primarily related to septic shock.

The aim of this study was to assess PMCT diagnoses of bowel obstruction based on their confirmation by autopsy and their relationship to the cause of death.

MATERIALS AND METHODS

The scan data were acquired as part of a forensic judicial investigation. The data usage is conformed with Swiss laws and ethical standards as approved by the ethics committee of the Canton of Zurich (written approval, KEK ZH-Nr. 2015-0686).

We reviewed all forensic imaging reports and all autopsy reports between January 2012 and March 2017 (n = 2614) regarding the detection of bowel obstruction. The exclusion criteria were as follows: decedent younger than 14 years (n = 1), a postmortem interval (PMI) greater than 3 days (n = 0), and trauma cases (n = 0). The final study population consisted of 10 cases (n = 10; females: n = 6 and males: n = 4). The mean age was 56.0 years (range: 17–94 years, median: 54.5 years). The PMI was calculated in hours based on the estimated time of death and the time and date of the PMCT examination. The time of death was determined in a range of hours; therefore, we used the mean value of this range for the indication of the PMI. The mean PMI was 22.6 hours (range: 4–58 hours; median: 18.5 hours). In all cases, the autopsy started 1–2 hours after the PMCT examination. All cases were reviewed by a board-certified radiologist with long-term experience in forensic imaging. In addition, gastrointestinal distension was graded as follows: 0, no distension; 1, distension of the duodenum and/or the stomach; 2, distension of the small bowel; and 3, distension of the large bowel. The presence of IHG was also noted. The PMCT diagnoses were confirmed by autopsy. The autopsy findings were deemed the criterion standard. In addition, histologic examinations, postmortem microbiology (liver smear, spleen smear, and blood culture), or toxicological analyses were performed

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according to autopsy findings. The PMCT findings were discussed in relation to the cause of death.

Case Histories

The following case histories are briefly described. Case 1: A 78-year-old man experienced abdominal pain and mentioned repeated vomiting a few days before he was found dead in his apartment. Case 2: A 75-year-old woman experienced repeated vomiting a few hours before she was found dead by her husband. Case 3: A cachectic 55-year-old woman was found dead in her seat on a public conveyance. Case 4: A 50-year-old woman was found lifeless on the floor of a communal toilet room. Approximately 48 hours before death, the decedent mentioned that she experienced flatulence and slight stomach problems, but shortly before death, she stated that she was symptom free. Case 5: A 45-year-old woman was found dead on her bed. The woman experienced stomach pains before her death. She underwent a gastric bypass surgery (Roux-en-Y anastomosis) years ago. Her body was surrounded by several diverse blister packs that mainly consisted of analgesics and antidepressants. Suicidal intentions were expressed before the incident. Case 6: A 17-year-old boy experienced fever and repeated vomiting. Respiratory insufficiency occurred immediately before death. The patient was intubated and died during resuscitation attempts. The decedent had trisomy 21. Case 7: A 62-year-old man underwent surgery because of bowel obstruction. Two days after the surgical procedure, he left the hospital on his own request. The next day (3 days after surgery), the man was found dead in his home. The decedent was surrounded by reddish vomit. Case 8: A 94-year-old woman experienced vomiting for several days before she was found dead on her bed by a relative. Case 9: A 54-year-old man underwent surgery for an umbilical hernia 2 weeks before his death. The patient experienced nausea after surgery and collapsed on his bed at home after intensive vomiting. Asystole was detected when the paramedics arrived. Case 10: A 31-year-old woman was observed as she collapsed in front of her room in a psychiatric clinic. Asystole was detected as the rescue service arrived. The patient was declared dead approximately 40 minutes after the incident. The psychiatric patient had type 2 diabetes mellitus.

Imaging Protocol

Postmorten CT was performed on a 128-slice scanner (Somatom Definition Flash, Siemens Medical Solutions, Forchheim, Germany) according to the literature.[19] The reconstruction

TABLE 1. Diagnostic Results

	Sex	Age (y)	PMI (h)	AR	PMCT Findings	Grade of Distension	IHG	PMCT Diagnosis	Confirmed by Autopsy	Cause of Death
Case 1	M	78	27	No	Mediastinal fat and distended loops of the large intestine cause elevated hemidiaphragm (left-sided) and intestinal narrowing	3	No	LBO	Yes	Septic shock
Case 2	F	75	61	No	Distended small bowel loops and a u-shaped, twisted loop	2	No	Small bowel volvulus	Yes	Septic shock
Case 3	F	55	21	No	Massive distended stomach and parts of the duodenum; possibly intramural gas in the small bowel	1	Yes	Duodenal obstruction and potential intestinal atrophy	Yes	Metabolic imbalance (starvation)
Case 4	F	50	4	Yes	Massive distended intestine, coffee bean sign, whirl sign, bird beak sign	3	No	Sigmoid volvulus	Yes	Septic shock
Case 5	F	45	16	No	Status after Roux-en-Y anastomosis, massive distension of the intestine, whirl sign, intramural gas, abnormal presence of gas in the peritoneal cavity, cerebral and pulmonary edema	3	No	Intestinal torsion and Petersen hernia with potential bowel perforation	No	Intoxication
Case 6	M	16	7	Yes	Massive distended stomach and parts of the duodenum; enlarged abdominal lymph nodes	1	No	Duodenal obstruction due to swollen abdominal lymph nodes	Yes	Septic shock
Case 7	M	62	15	No	Status after abdominal intervention, massive distension of the intestine, bird beak sign	3	Yes	Large bowel volvulus with potential adhesion and peritonitis	Yes	Septic shock
Case 8	F	94	11	No	Massive distended stomach and parts of the small intestine, whirl sign	2	No	Small bowel volvulus	Yes	Septic shock
Case 9	M	54	58	Yes	Status after abdominal intervention, massive distended stomach and parts of the small bowel, umbilical hernia with SBO	2	Yes	Adhesive SBO and peritonitis	Yes	Septic shock
Case 10	F	31	30	Yes	Massive distension of the intestine, potential intramural gas (large bowel), cerebral edema, cardiomegaly	3	Yes	Potential large bowel ischemia with pneumatosis intestinalis	No	Acute cardiac failure

The PMCT diagnoses of bowel obstruction were confirmed by autopsies in 8 of 10 cases. In all of these cases, the cause of death was deemed consistent with septic shock with the exception of case 3. The cause of death in case 3 was determined to be metabolic imbalance due to starvation. In 2 of 10 cases, the autopsy did not confirm the PMCT diagnosis (cases 5 and 10).

AR indicates artificial respiration.

parameters of the thorax and abdomen scan were as follows: 120 kV, 400 reference mille-ampere-second dose modulation (CAREdose4D, Siemens, Forchheim, Germany), 1-mm slice thickness, and 0.6-mm increment. Reconstructions were made in a soft tissue window with a soft kernel and an osseous window with a hard kernel.

RESULTS

The results are listed in Table 1. The PMCT diagnoses were large bowel obstruction (LBO) (case 1), small bowel volvulus (cases 2 and 8), duodenal obstruction (cases 3 and 6), sigmoid volvulus (case 4), intestinal torsion and Petersen hernia with potential bowel perforation (case 5), large bowel volvulus with potential adhesion (case 7), adhesive small bowel obstruction (SBO) (case 9), and potential large bowel ischemia with pneumatosis intestinalis (case 10). In all cases, parts of the gastrointestinal tract were distended (grade 1: n = 2, grade 2: n = 3, and grade 3: n = 5). Intrahepatic gas was noted in 4 of 10 cases (cases 3, 7, 9, and 10).

The PMCT diagnoses of bowel obstruction were confirmed by autopsies in 8 of 10 cases. In all of these cases, the cause of death was deemed consistent with septic shock with the exception of case 3. Histology confirmed necrotic tissue and microbiology revealed a large amount of *Enterobacter cloacae* and/or *Enterococcus faecalis* in the liver, spleen, and blood. The cause of death in case 3 was determined to be metabolic imbalance due to starvation. In 2 of 10 cases, the autopsy did not confirm the PMCT diagnoses of intestinal torsion and bowel perforation (case 5) or bowel ischemia with pneumatosis intestinalis (case 10). The cause of death in case 5 was determined to be respiratory paralysis due to intoxication based on the toxicological analysis. The cause of death in case 10 was deemed acute cardiac failure.

DISCUSSION

The PMCT findings of bowel obstruction correlated with the autopsy in 8 of 10 cases. In 7 of the cases, the cause of death was deemed consistent with septic shock based on macroscopic autopsy findings, histologic examination, and postmortem microbiology. Other causes of death could be excluded. Interleukin-6 or C-reactive protein levels were not measured.

The small number of cases in this study revealed decedents with bowel obstruction that were not frequently seen in our institute of forensic medicine. These cases may be more frequent in clinical pathology than in forensic pathology. Therefore, forensic pathologists may be less trained to detect bowel obstructions on PMCT. Determining bowel obstruction on PMCT requires clear radiological signs.

All cases displayed massive distended parts of the gastrointestinal tract. However, bowel distension in postmortem imaging may be considered nonspecific because of decomposition-related changes. The decomposition process is dependent on several factors,[20] but generalized bloating starts to appear after 72 hours postmortem according to the literature.[21] The PMI of all decedents in this study was less than 72 hours (mean: 22.6 hours; range: 4–58 hours). However, a study by Klein et al[22] revealed that bowels were already distended a few hours after death. The authors detected postmortem changes up to 36 hours using PMCT. In 1 case, they measured a bowel volume that almost trebled between 6 and 32 hours after death. Postmortem bowel distension presumably occurs because of gas-producing bacteria in the intestinal flora in combination with an absence of intestinal motility.[23,24] Gastrointestinal distension may also occur because of artificial respiration during resuscitation measures.[24,25] Resuscitation measures and artificial respiration were performed in cases 4, 6, 9, and 10 (Table 1). Therefore, massive bowel distension may not be a specific sign for bowel obstruction on PMCT. However, if massive bowel distension is detected in decedents with a PMI of less than 72 hours, we recommend taking a closer look at the bowels for further radiological signs of bowel obstruction.

Apart from the dilated bowel, PMCT clearly depicted an elevated hemidiaphragm (left-sided) containing mediastinal fat and distended loops of the large intestine in case 1. The PMCT findings led to the diagnosis of LBO, which was confirmed by autopsy (Fig. 1). In 2 other cases, PMCT indicated duodenal obstruction (cases 3 and 6), which was confirmed by autopsy. Case 3 displayed massive stomach distension. No resuscitation

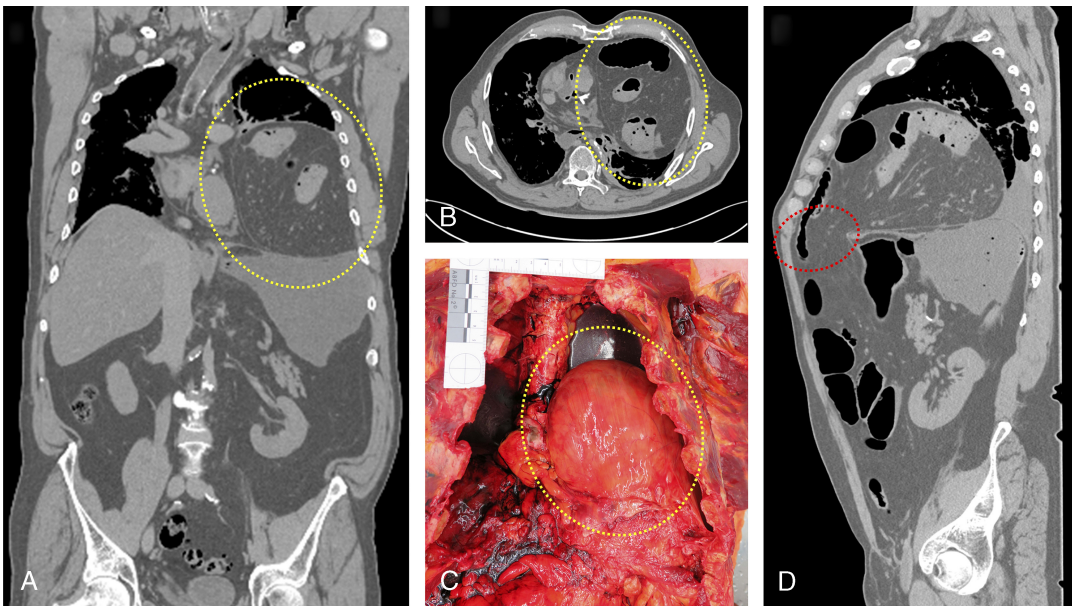

FIGURE 1. Case 1 depicted an elevated hemidiaphragm (left-sided) caused by distended loops of the large intestine and mediastinal fat (A-C: yellow circle). Large bowel obstruction was diagnosed on PMCT (D: red circle) and confirmed by autopsy.

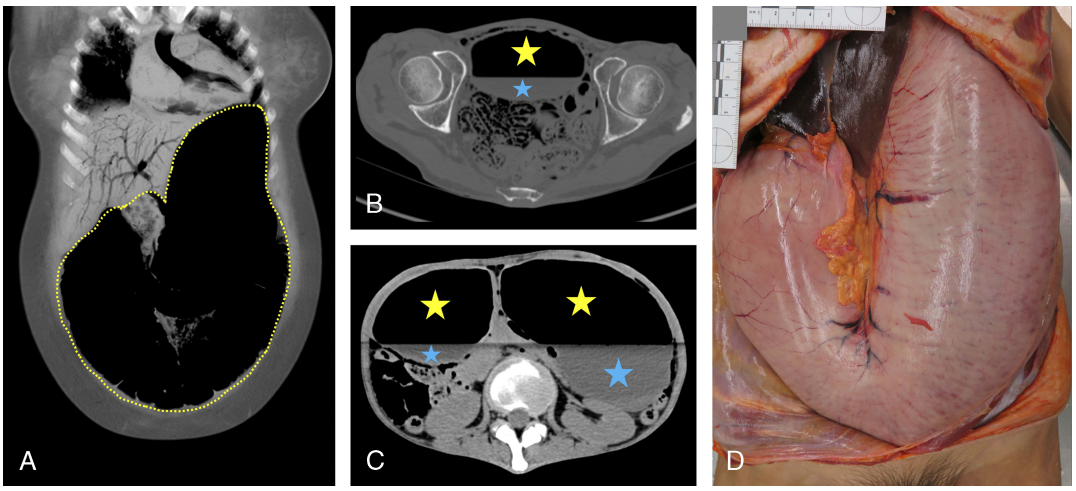

FIGURE 2. The decedent in case 3 displayed a massive distended (A: yellow circle) stomach, and parts of the duodenum were distended. The distended stomach and duodenum displayed gas-filled (B, C: yellow asterisks) and fluid-filled (B, C: blue asterisks) contents. A duodenal obstruction was diagnosed on PMCT. At autopsy, the obstruction was confirmed, which caused a massive distended stomach (D).

measures or artificial respiration was performed in this case. Postmortem CT indicated a duodenal obstruction, and intestinal atrophy was assumed, possibly due to a disease of the nerves or muscles of the gastrointestinal tract (Fig. 2). The PMCT findings in combination with the cachectic body (body mass index: 11.68 kg/m^2) led to the presumption of death from starvation. Death from starvation was confirmed based on the toxicological analysis, which showed high beta-hydroxybutyric acid and acetone levels. Case 6 described a rare case of sinus histiocytosis with massive lymphadenopathy (also known as Rosai-Dorfman disease[26,27]), which led to duodenal obstruction due to benign, enlarged lymph nodes (Fig. 3). In this case, the massive stomach distension may have been partially caused by artificial respiration. In 4 cases, PMCT indicated bowel obstruction due to a volvulus (cases 2, 4, 7, and 8), which was confirmed by autopsy. A volvulus describes torsion of the intestine and its mesentery along its mesenteric axis,[28–30] which leads to a closed-loop obstruction.[30,31] The PMCT findings of a small bowel volvulus were depicted in cases 2 and 8. In case 2, distended, u-shaped loops converging toward a point of obstruction indicated a volvulus. In case 8, a whirl sign indicated a volvulus of the small bowels (Fig. 4). The whirl sign was first mentioned by Fisher[32] in 1981 as loops encircling the mesenteric vessels displayed in a whirl-like pattern.[31] A small bowel volvulus rarely occurs in adults,[28,33] although a volvulus of

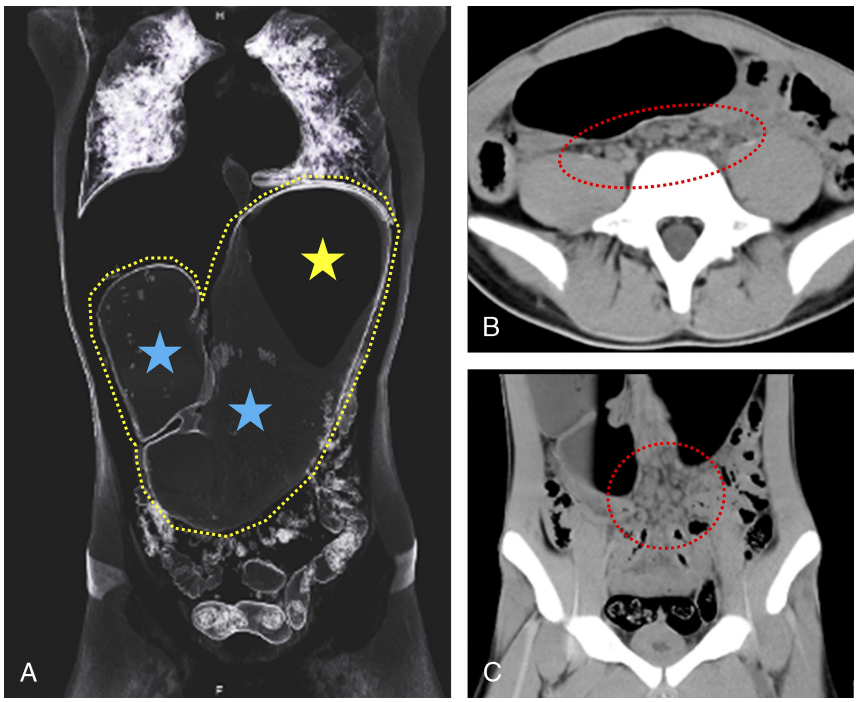

FIGURE 3. The decedent in case 6 displayed massive distension of the stomach (A: yellow marking) with gas-filled (A: yellow asterisk) and fluid-filled (A: blue asterisks) contents. In addition, a duodenal obstruction due to swollen abdominal lymph nodes (B, C: red circle) was depicted on PMCT and confirmed by autopsy.

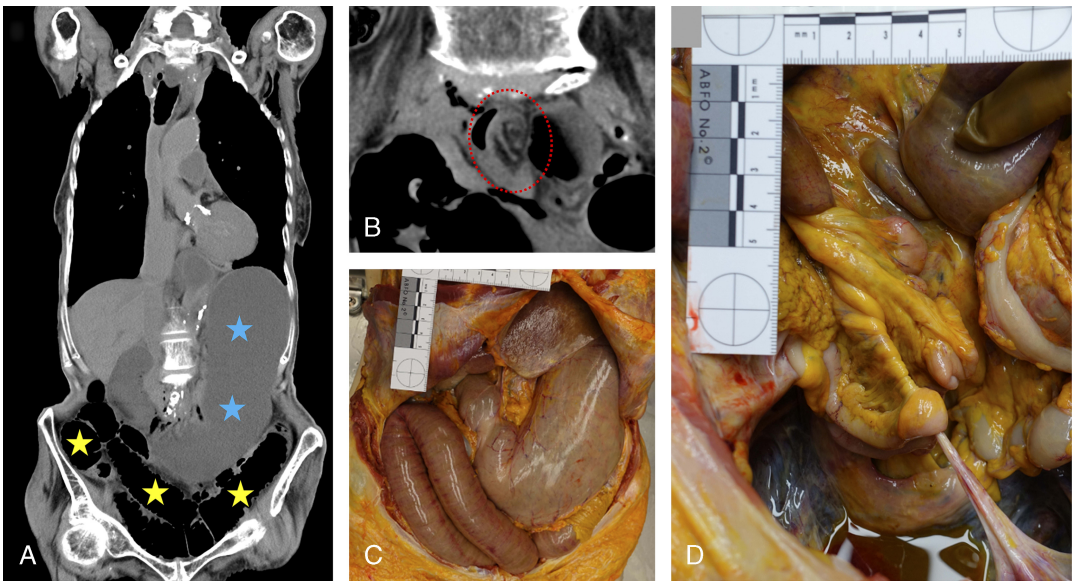

FIGURE 4. Case 8 displayed a distended gas-filled (A: yellow asterisks) and fluid-filled (A: blue asterisk) intestine. The PMCT displayed a whirl sign in the coronal view (B: red circle). Autopsy (C, D) confirmed the PMCT diagnosis of small bowel volvulus.

the colon is more common.[33,34] The frequent volvulus type in the large bowel segments is the sigmoid volvulus.[35,36] Case 4 displayed a common sigmoid volvulus on PMCT, which was clearly indicated by the coffee bean sign, the bird beak sign, and the previously mentioned whirl sign (Fig. 5). The coffee bean sign is created by the apposition of the medial walls (cleft of the bean) and the lateral walls (shape of the bean) of the dilated loop.[29] The bird beak sign is illustrated by a progressive tapering and converging of the afferent and efferent loop segments at the point of twisting.[3,29] A bird beak sign was also depicted in case 7, which indicated LBO due to a large bowel volvulus with potential adhesion after the surgical intervention a few days previously. In

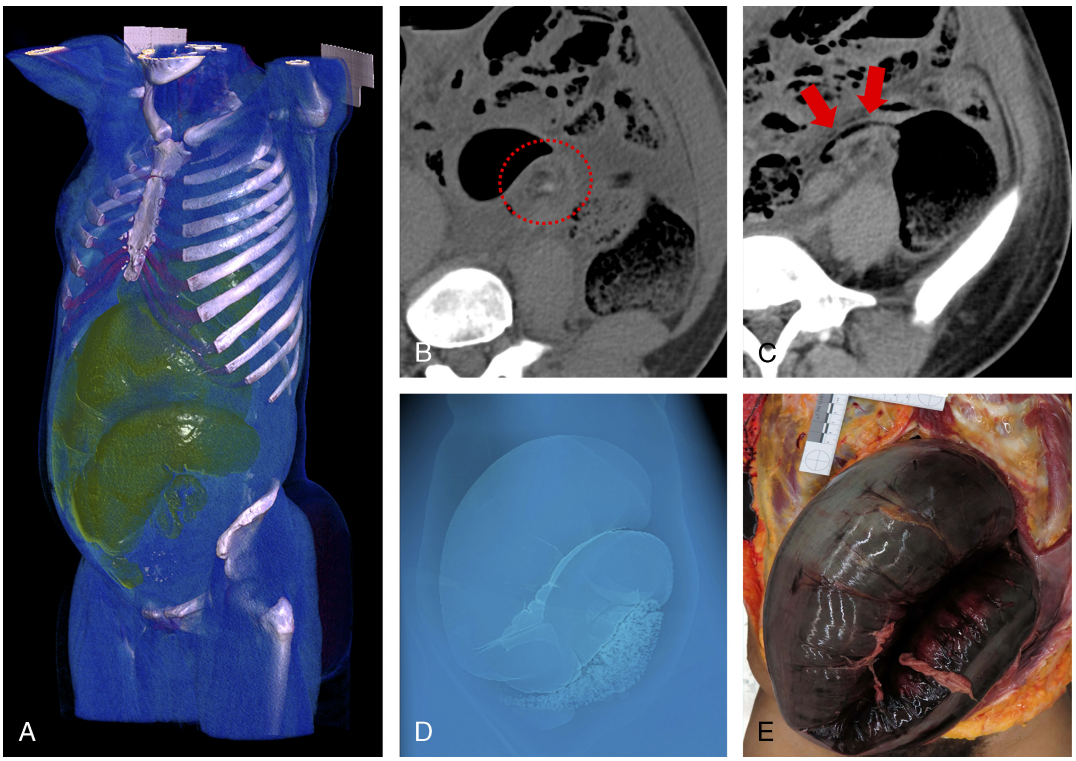

FIGURE 5. Case 4 displayed a massive distended intestine (A), a whirl sign (B: red circle), a bird beak sign (C: red arrows), and a coffee bean sign (D), which clearly indicated a sigmoid volvulus. The PMCT diagnosis was confirmed by autopsy. The autopsy revealed necrotic large bowel tissue (E).

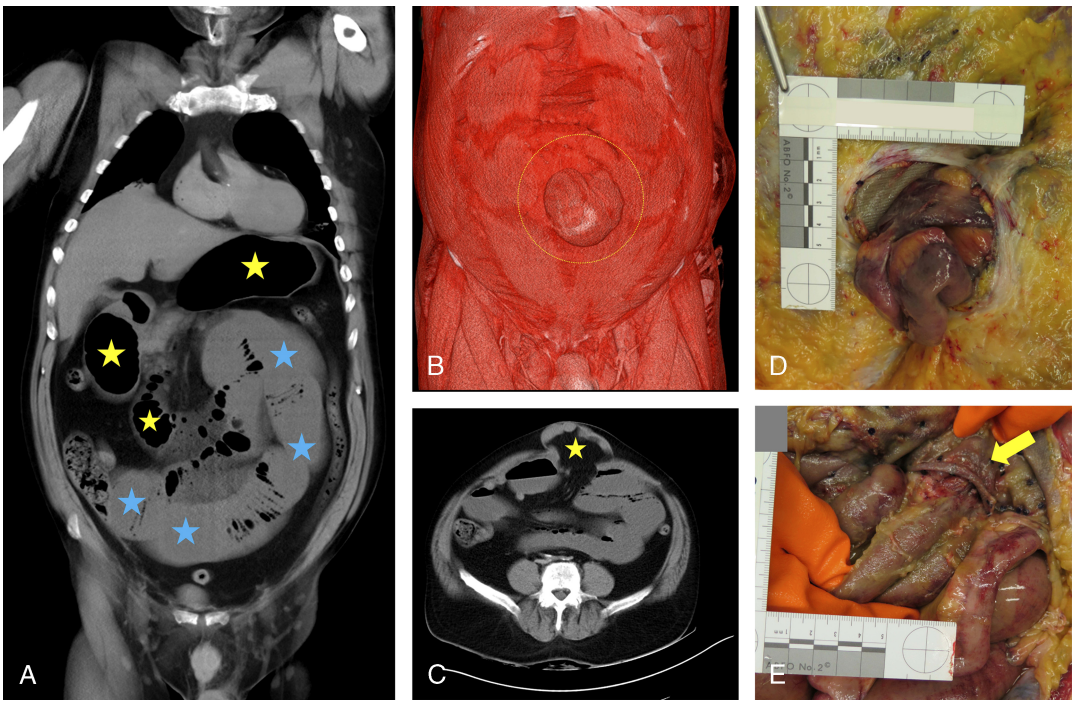

FIGURE 6. The decedent in case 9 displayed a status after abdominal intervention with a distended gas-filled (A: yellow asterisks) and fluid-filled (A: blue asterisks) stomach and distension of parts of the small bowel. An umbilical hernia (B: yellow circle; C: yellow asterisk) led to adhesive SBO after surgery. The PMCT diagnosis of bowel obstruction was confirmed by autopsy (D). Bowel obstruction was caused by detachment of the surgical mesh (E: yellow arrow marks the surgical mesh). In addition, the autopsy revealed peritonitis (E).

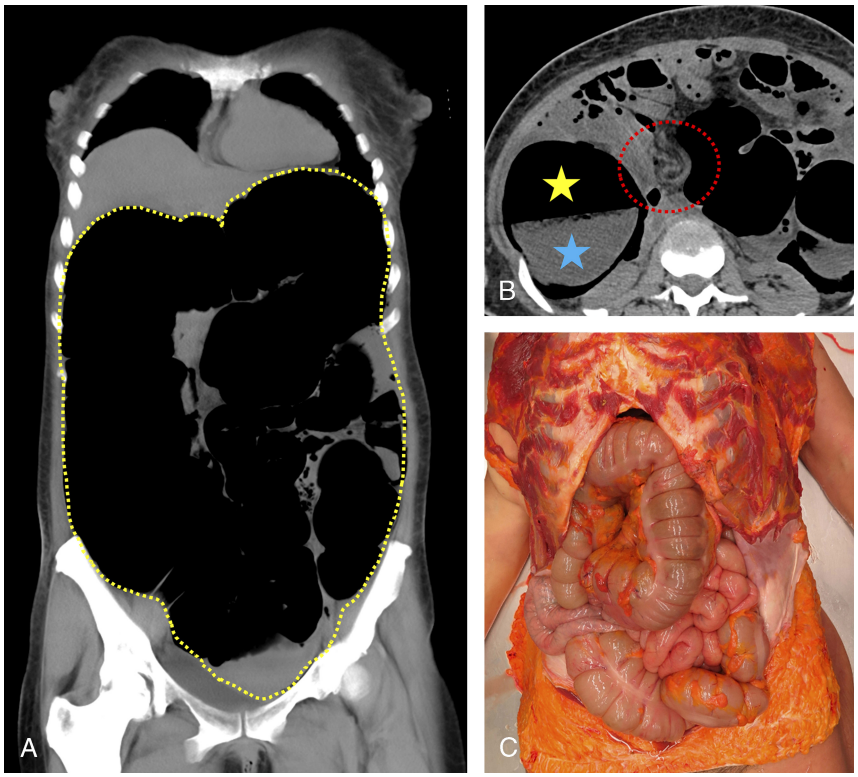

FIGURE 7. Case 5 displayed the status after Roux-en-Y anastomosis with massive distension of the intestine (A: yellow marking). The distended bowel was gas filled (B: yellow asterisk) and fluid filled (B: blue asterisk). The PMCT depicted a whirl sign (B: red circle), which indicated intestinal torsion. However, apart from bowel distension (C), the autopsy did not confirm the PMCT diagnosis. The cause of death was determined to be intoxication based on the toxicological analysis.

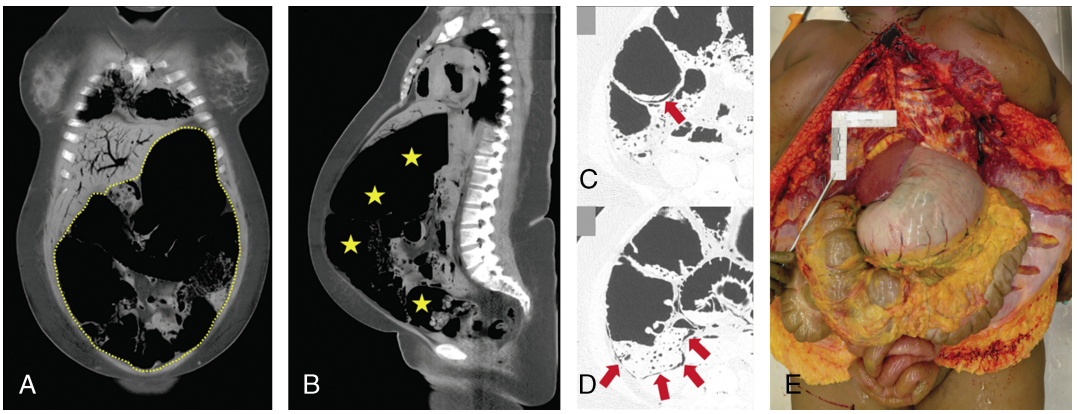

FIGURE 8. Case 10 displayed massive distension (A: yellow marking) of the gas-filled (B: yellow asterisks) intestine. Further potential intramural gas (C, D: red arrows) was assumed to be an explanation for bowel distension, which led to the diagnosis of potential large bowel ischemia with pneumatosis intestinalis. However, apart from bowel distension (E), the autopsy did not confirm the PMCT diagnosis. The cause of death was deemed to be acute cardiac failure. The cause of the bowel distension remained unclear.

addition, peritonitis was detected during the autopsy. Case 9 underwent surgical intervention 2 weeks before death. A mesh was used to repair the hernia. The PMCT indicated an adhesive SBO due to the umbilical hernia, which was confirmed by autopsy. Autopsy revealed that the surgical mesh became detached, leading to penetration of the bowel loops into the hernia sac. In addition, peritonitis was detected during autopsy (Fig. 6). The cause of death was deemed consistent with septic shock due to bowel obstruction and peritonitis based on macroscopic autopsy findings, histologic examination, and postmortem microbiology. Furthermore, other causes of death could be excluded.

The autopsy did not confirm intestinal torsion in case 5 despite the depiction of a whirl sign. In case 5, a Petersen hernia after Roux-en-Y gastric bypass was interpreted, which was a known risk factor for this surgical procedure.[37,38] In addition, a perforation was assumed because of the small amounts of gas in the abdominal cavity. The distended bowel, the whirl sign, the status after Roux-en-Y gastric bypass surgery, and the woman's complaints of abdominal pain before her death led to the strong presumption of intestinal torsion (Fig. 7). However, the autopsy did not detect bowel pathologies or injuries (in this case, perforation or twisted intestinal loops). Regarding the twisted loops, we speculated that the distended bowels might have untwisted during dissection of the abdominal cavity. Furthermore, intestinal torsion in an early stage may explain the absence of pathological findings of the intestinal wall at autopsy. However, from the forensic perspective, intoxication was primarily considered as a potential cause of death because of the presence of several blister packs at the site where the body was found. Additional PMCT findings were cerebral and pulmonary edema, which are signs of intoxication.[39] Toxicological analyses confirmed intoxication due to fluvoxamine. In case 10, pneumatosis intestinalis due to gas within the intestinal wall was assumed, which led to the diagnosis of potential bowel ischemia (Fig. 8). Pneumatosis intestinalis is described as the presence of gas within the intestinal wall, and bowel ischemia is a life-threatening cause of pneumatosis intestinalis according to the literature.[40,41] Autopsy could not confirm the PMCT findings because the intestinal walls and the intestinal mucosa were unsuspicious. In contrast, clinical radiological gas from decomposition is a normal postmortem finding,[14] which may explain the intramural gas in this case. Gas accumulations were also present in several abdominal organs, which made the interpretation more challenging. In addition, PMCT displayed cerebral edema and cardiomegaly (a 450-g heart weight was measured at autopsy). Because the decedent was in a psychiatric institution, toxicological examinations were performed; however, the toxicological analyses revealed no indication of intoxication. The decedent had diabetes mellitus, but the blood glucose measurement during resuscitation procedures and postmortem-measured beta-hydroxybutyric acid values showed normal values. Therefore, the cause of death was deemed acute cardiac failure in accordance with the enlarged heart. The reason for bowel distension in this case could not be clearly determined. An explanation could be long-term prescribed medication. Another explanation may be gastrointestinal dysmotility symptoms and gastroparesis due to diabetes mellitus, which can occur in patients with type 2 diabetes.[42,43]

Bowel obstruction can be an indication for potential sepsis in decedents. In 7 of 10 cases, the cause of death was deemed consistent with septic shock based on macroscopic autopsy findings, histology and microbiology. Postmortem CT displayed bowel obstruction in all of these cases. Autopsy and histology confirmed the relevance of the PMCT findings by the detection of necrotic tissue. Liebman et al[16] reported that mucosal damage, bowel distension, and sepsis predisposed the living to hepatic portal venous gas. In our study, only 2 cases displayed IHG (cases 7 and 9), which was related to sepsis as the cause of death (Table 1). A correlation between IHG and sepsis was not confirmed. Takahashi et al[18] demonstrated a strong correlation between the presence of IHG and intestinal distension in decedents. In our study, only 4 of 10 cases with bowel distension displayed IHG, which did not allow confirmation of a correlation between IHG and bowel distension.

CONCLUSIONS

Postmortem CT is a valuable method for the depiction of bowel obstruction in decedents with a PMI of less than 3 days. The detection of bowel obstruction may be a diagnostic hint toward potential sepsis in decedents. Especially when no other cause of death is detectable, further examinations regarding sepsis should be considered.

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